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USE OF STRATIFIED RANDOM SAMPLES IN A LAND USE STUDY*

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THIS paper demonstrates the use of stratified random sampling and statistical analysis applied to a land-use problem. The objectives of the inquiry in which these techniques were used were (1) to locate and map the swamps and marshes of eastern Wisconsin (Fig. 1),[1] (2) to map the utilization of this land, and (3) to evaluate its significance to the economy of the region. Only the first two objectives will be treated in this paper. Although the term "wet land" has been used to designate the subject under consideration, the term "organic soils" could have been used as well. It was found in the field that, in places that had detailed soil map coverage, the writer's classification of "wet land" included only those areas on the map designated as peat or muck.

USE OF SAMPLES

Preliminary investigations indicated that there were about a million acres of poorly drained land in the area. This type of land can be found in all except one of the almost 300 townships which make up the hundred thousand square miles of eastern Wisconsin. The amount and distribution of this land, as well as limited time and funds, clearly indicated that not all of it could be studied at first hand. Some form of sampling was indicated. A search of the literature revealed that not much sampling for geographic research had ever been done. True, isotherms, isohyets, contours, and the like must of necessity be based on samples, but they represent ingredients of the landscape which change from place to place at a more or less even rate. Furthermore, these changes are changes in degree rather than changes in kind. Land use, on the other hand, changes abruptly from one kind to another.

This fact, probably more than any other, has hindered the development of sampling procedures for land-use study. Traverses, really a form of sampling, have

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[1] Eastern Wisconsin is defined as that part of the state having Late Wisconsin drift and lying east of the Magnesian Escarpment. Practical considerations of the research problem dictated that the western boundary coincide with political boundaries. Milwaukee County as well as parts of Brown, Calumet, and Outagamie counties, all parts of eastern Wisconsin, are omitted from the study because of lack of data. Included within the problem area are thirteen whole counties and parts of eleven others. A "swamp" is distinguished from a "marsh" by the fact that it is wooded. A marsh has no trees but may have brush.

many variations and are useful for certain purposes.[2] A comparatively short traverse, properly laid out across the grain of the landscape, can be expected to reveal how much land is in a given use, but by itself it is not very helpful in telling how the utilizations are distributed. Closely spaced foot traverses, such as used by the Wisconsin Land Economic Inventory,[3] can answer both the "how much" and "where" questions, but one individual could never hope to cover a large field area by this method. In addition, the prospect of making traverses across swamps and marshes was not very attractive.

The problem could have been solved by air photo interpretation, but the only such photography available at the time was made in the late 1930's. Though still good for identifying the wet land, it was inadequate for a current land-use study because of the many changes which have taken place in the intervening years.

The possibility of making broad generalizations based upon observations of a few "typical" areas was ruled out from the start. If one knew enough about an area to recognize that which is truly typical, there would be no point in doing the research at all because the facts would already be known to the investigator. Each investigator is allowed much leeway in choosing units for detailed study. However, if one plans to use statistical analysis, he must choose his sample in such a way as to give every individual in the universe an equal chance of being chosen.

SIZE OF THE SAMPLE

Sampling methods are usually used because of the impracticality of studying the universe. The smaller the sample is, however, the more necessary it is that the individuals which make it up be chosen with care. In light of the analysis techniques to be used later, it was decided that towns[4] were to be the individual

[2] See C. C. Colby, "The Railway Traverse as an Aid in Reconnaissance," *Annals*, Association of American Geographers, Vol. 23 (1933), pp. 157–164; G. D. Hudson, "Methods Employed by Geographers in Regional Surveys," *Economic Geography*, Vol. 12 (1936), pp. 98–104; Malcolm J. Proudfoot, "Sampling with Traverse Lines," *American Statistical Association Journal*, Vol. 37 (1942), pp. 265–270.

[3] The Wisconsin Land Economic Inventory, organized in 1928 and expanded when funds became available in the 1930's, sought to map all of the land cover in the state except that in Milwaukee County. Data for the maps were gathered by field men who made foot traverses one eighth of a mile apart in the southern counties and one quarter of a mile apart in some of the sparsely settled northern counties. These field men used a pace scale to record the distance traveled through each specific type of cover. The plan was to have the traverse data incorporated into maps, but before maps could be made for all counties, the work slowed down considerably because of lack of funds. Published maps at a scale of one inch to the mile are available for most of the counties in eastern Wisconsin. In addition to the published maps, there are a number of unpublished sheets existing only in manuscript form. These are on file at the Land Economic Inventory office in Madison. The maps were used in this study and proved valuable both in the field and in the office. Indicated, in addition to the usual cultural features, are all of the various kinds of forest cover, brush, upland pasture, cropland, and poorly drained land.

[4] As used in this paper, the word "town" means a minor civil division, as distinguished from a "township," which is a measure of land. Most towns are composed of whole townships, but some are larger and some smaller.

units in the sample. Towns are the smallest division of land for which statistics are gathered. In Wisconsin more data are available on a town basis than in most states. Information contained in the 1945 *Census of Agriculture* has been published on a town basis.[5] Also, town assessors' records have been consolidated and give much valuable data concerning land use on a year to year basis.[6]

Limited time and funds dictated that only ten towns could be studied in detail. A sample of this size would include between three and four percent of the universe, which had 293 towns. Admittedly this is a small sample, but size alone is not the sole measure of sample validity. For instance, prices paid for grain and butterfat are based on samples much smaller than that. If there is any basis at all for the small-sample theory, ten towns should adequately represent eastern Wisconsin, if a proper procedure is followed in choosing these towns. The aim of any sampling procedure is to draw sample units which, when grouped together, possess the same degree of diversity as the universe from which drawn.[7] Actually, eastern Wisconsin is not as diverse as one might expect. It is a cuestaform plain, underlain by limestone, covered with new glacial drift, and it is devoted to the dairy economy. This homogeneity made the choice of a representative sample much simpler than it would have been had the area been more diverse.

The area is not so homogeneous, however, as to encourage complete random choosing of such a small sample. There is a gradation of agricultural intensity from high values in the south to lower values in the north, as indicated by percent of land in farms, percent of farm land in crops, value of farm land, and other measures. It was assumed that such a situation with regard to land in general would be reflected in the intensity to which wet lands were utilized.

INVESTIGATIONS PRIOR TO CHOOSING THE SAMPLE

A close examination of the distribution of the wet land as revealed by the original surveyors' maps indicated that the amount of wet land per town ranged from over 24,000 acres in the wettest town to less than 100 in the driest.[8] A comparison of the surveyors' maps with those made by the Land Economic Inventory, eighty to a hundred years later, showed that these two sources disagreed widely as to the amount of wet land in some of the towns, the Land Economic Inventory more often than not giving the smaller acreage. This is understandable because the Land Economic Inventory did not consider hay marsh, drained cropland, or, usually, cleared swamp land as wet land. Later field investigation revealed another reason

[5] Wisconsin Crop and Livestock Reporting Service, *County Agriculture, Bulletin 202 and Supplements* (Madison, Wisconsin, 1947–48). There is a separate bulletin for each county.

[6] The town assessors' records are on file in the office of the Federal-State Crop Reporting Service located in the state capitol, Madison, Wisconsin.

[7] For a good elementary treatment of the sampling theory, see George R. Davies and Dale Yoder, *Business Statistics* (2d ed., 1941). The same or a similar reference will also prove useful in following the methodology used later.

[8] These documents are on file in the office of the Commissioner of Public Lands in the state capitol, Madison, Wisconsin. They date from the 1830's, 1840's and 1850's.

for this. The surveyors, who were not required to go inside a square mile of land while surveying it, often mistakenly inferred that a swamp extended all the way across a section when actually it didn't. Several surveyors were prone to mark some land as impassable swamp and not "run the section line" at all, even though a fairly large "island" of upland timber would have been discovered if the line had been run. Very puzzling, at first, were the cases in which the Land Economic Inventory showed more wet land than the original survey. This occurred mainly because many of the smaller marshes lying some distance from a section line went unnoticed and unmapped by the surveyors, but were mapped by the Land Economic Inventory.

CHOOSING THE SAMPLE

The facts uncovered during the preliminary investigations were invaluable in setting up the controls to govern the choice of sample towns. The first step was to change the number of units in the universe from 293 to a more manageable 290. This was done by eliminating one town in which the Land Economic Inventory found no wet land at all and combining two pairs of smaller towns into two pseudo-towns. The pseudo-towns were hereafter treated as one town and the area was thought of as having 290 towns.

The second step was to place the 290 towns in an array according to the amount of wet land they had at the time of the original survey. The town having the least wet land was placed at the head of the array, and the one having the most was placed at the foot. The whole array was divided into groups by counting off the first fifty-eight to form the first group, the second fifty-eight for the next group and so on until five groups of towns were formed. By stratifying a diverse universe such as this and choosing an equal number of units from each strata, one can expect to have a sample more representative of the universe than one chosen at random.

The third step was to rearrange the towns within each of the five groups into arrays, with the town having the most decrease in wet land acreage between the time of the Land Survey and the Land Economic Inventory at the head of the list, and the town having the most increase at the foot of the list. Each group was then divided into two parts by counting off the first twenty-nine for a "much decrease" subgroup leaving the last twenty-nine to form a "little decrease" subgroup. The plan was to draw one town from each of the ten subgroups to form the sample.

The fourth step was to divide a minor civil divisions map into southern, middle, and northern thirds with the boundary lines running as nearly east-west as town lines would permit. The southern and middle thirds had one hundred towns each and the northern third with larger towns had ninety. It was planned that at least three sample towns should come from each third with the tenth sample falling wherever chance would place it. However, this control was not to be placed into operation unless it was found after the sample was drawn that one of the thirds had less than three or more than four sample towns. If that situation had arisen the entire sample would have been rejected and a new one chosen which met the provisions of this control.

Having established the controls, twenty-nine filing cards were numbered consecutively from one to twenty-nine and thoroughly shuffled. A card was then drawn to indicate which town of the first subgroup was to be a part of the sample. It was

TABLE I

WET LAND ACREAGE IN THE TEN SAMPLE TOWNS ACCORDING TO THREE SOURCES

Sample town, and county from which drawn	Original survey acreage	Land Economic Inventory acreage	Actual acreage (writer's field maps)
Aztalan, Jefferson	1,220	1,200	1,558
Bailey's Harbor, Door	5,250	4,232	6,905
Dunn, Dane	1,720	3,210	2,746
Hartland, Shawano	7,000	2,994	3,605
Linn, Walworth	1,520	659	825
Lowell, Dodge	10,250	11,547	11,007
Nepeuskum, Winnebago	4,900	5,489	4,082
Oconomowoc, Waukesha	3,000	2,391	3,376
West Bend, Washington	710	1,252	1,252
Woodville, Calumet	2,930	1,186	1,835
Total	38,500	34,160	37,191

number 21 and accordingly the twenty-first town in this subgroup, Aztalan in Jefferson County, became the first sample town. The card was returned to the

TABLE II

SAMPLE AND CHECK SAMPLE COMPARED*

Item compared	Sample	Check sample
Total land acreage (C)**	207,000	222,000
Wet land acreage (S)	38,000	38,000
Wet land (S) % of total area (C)	18.3%	17.1%
Wet land acreage (L)	34,000	29,000
Wet land (L) % of total area (C)	16.4%	13.0%
Farm land acreage (C)	188,000	198,000
Farm land (C) % of total area	91.0%	89.2%
Number of farms (C)	1,670	1,720
Average size of farm (C)	113	115
Cropland acreage (C)	107,000	113,000
Cropland (C) % of farm land (C)	56.9%	57.1%
Plowable pasture (C) % of farm land (C)	11.3%	11.9%
Farm woodland (C) % of farm land (C)	9.3%	9.3%
Other farm land (C) % of farm land (C)	21.2%	20.7%
Corn acreage (A) % of cropland (C)	30.0%	29.3%
Tame hay acreage (A) % of cropland (C)	32.7%	32.5%
Pasture not wooded or plowed (A) % of farm land (C)	12.1%	10.6%

* The towns in the check sample are Arlington, Columbia; Harrison, Calumet; Dunkirk, Dane; Randall, Kenosha; Vinland, Winnebago; Abrams, Oconto; Erin, Washington; Columbus, Columbia; Lincoln, Kewaunee; and Palmyra, Jefferson.

** A = assessors' reports; C, census; L, Land Economic Inventory; S, land survey.

pack, the pack shuffled again, and another card was drawn to determine which town in the second subgroup would be added to the sample. The process was repeated until a sample had been drawn from each subgroup. The towns thus chosen to be

the sample are listed together with their acreage of wet land (Table I) and shown in their location in eastern Wisconsin (Fig. 1).

Next, a check sample of ten towns was chosen by the same method to serve as

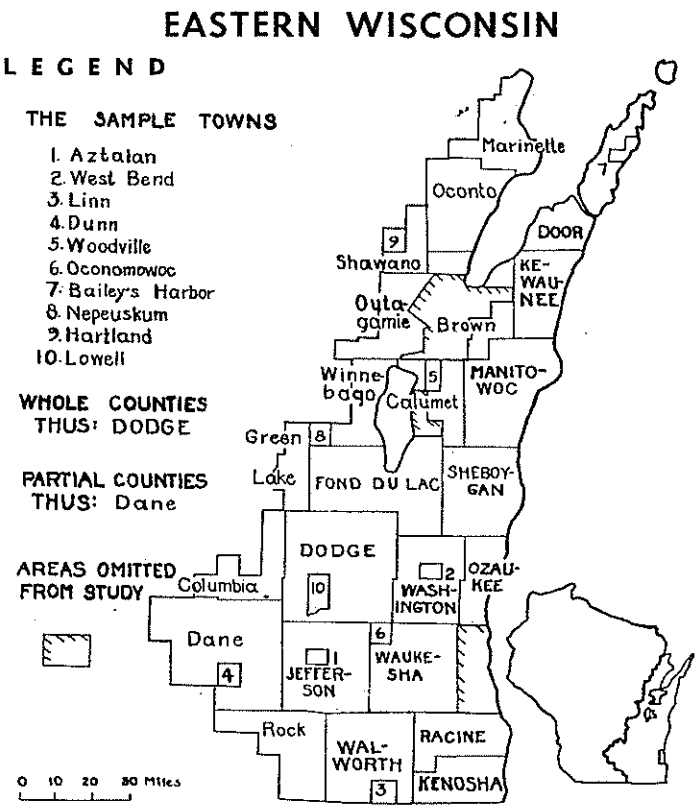

FIG. 1

a basis of comparison. It may be argued that if two stratified random samples compare well with regard to known data, they could also be expected to compare well with regard to unknown data and that either or both would be representative of the universe. Such a comparison (Table II) revealed that there was indeed close

agreement, and the field study of the sample was begun with strong hopes for success.[9]

MAPPING LAND USE

Each of the ten sample towns was visited and the utilization of the wet land was recorded on 1 : 20,000 vertical aerial photographs. The recorded land was classified as wasteland, open pasture, pastured swamp hardwoods, non-pastured swamp hardwoods, tamarack, white cedar, balsam, fir, hay marsh, and cropland. If the land was in crop, notation was made of the kind of crop.

In order for a given piece of land to be classed as wet, and thus recorded, a few simple requirements had to be met. The surface had to appear flat to the eye, have a high percentage of humus, and be black in color. The presence of marsh or swamp vegetation was also a valuable clue, as was the presence of drainage ditches. It was also noted that the contact between dry upland and wet bottom land occurred at abrupt changes in slope. This knowledge greatly facilitated the drawing of boundaries on the photographs, because the changes in slope appeared on the photographs as definite changes in tone.[10] After the field data were gathered, acreages devoted to various uses were measured from the photographs (Table III) with a dot planimeter, and recorded on analysis paper.

TABLE III

WET LAND UTILIZATION IN THE SAMPLE TOWNS, BY ACRES
(BASED ON FIELD DATA)

Sample town	Swamp	Individual agricultural uses			Swamp and agricultural uses	Waste-land	All wet land
		Open pasture	Wild hay	Crop-land			
Aztalan	159	1,180	23	105	1,467	91	1,558
Bailey's Harbor	6,392	55	0	0	6,447	458	6,905
Dunn	45	828	6	35	914	1,832	2,746
Hartland	2,879	528	20	61	3,488	117	3,605
Linn	0	657	15	38	710	115	825
Lowell	709	5,775	999	794	8,277	2,730	11,007
Nepeuskum	4	1,580	365	48	1,997	2,085	4,082
Oconomowoc	712	1,697	64	301	2,774	602	3,376
West Bend	630	470	3	20	1,123	129	1,252
Woodville	1,016	550	2	108	1,676	159	1,835
Total	12,546	13,320	1,497	1,510	28,873	8,318	37,191

ESTIMATING TOTAL AMOUNT OF WET LAND

A comparison of the total acreages of wet land yielded by the three sources (Table I) would seem to indicate that fairly good estimates of the actual acreages

[9] The close agreement of two samples in regard to several items does not prove beyond all shadow of a doubt that they will agree as well on other points, but it is highly likely. It is true, however, that if two samples do not compare well with regard to known data, there is little hope that they will have much agreement insofar as unknown characteristics are concerned.

[10] Maps of the Soils Survey and Land Economic Inventory as well as tracings of the Land Survey maps were used in the field. It was never necessary to record any wet land not mapped on at least one of these three maps, but the shapes of many areas were changed.

in the towns not chosen as sample units could be made by averaging the figures of the original survey and the Land Economic Inventory. However, consideration of some of the individual towns dispels this hope and prompts one to search further for a method by which actual acreages may be estimated. Further study of the table as a whole suggests that somewhat better estimates might be made by using the Land Economic Inventory figures alone. Yet even such a method would not employ the available data in the most useful manner.

When considering the relationship between Land Economic Inventory acreages and actual acreages in groups of towns rather than in all ten at once, the relationship becomes more apparent. When the five "much decrease" towns (Table IV)

TABLE IV

WET LAND ACREAGES IN THE "MUCH DECREASE" TOWNS, BY VARIOUS SURVEYS

Sample town	Land survey	Land Economic Inventory	Field maps
Aztalan	1,220	1,200	1,558
Bailey's Harbor	5,250	4,232	6,905
Hartland	7,000	2,994	3,605
Linn	1,520	659	825
Woodville	2,930	1,186	1,835
Total	17,920	10,271	14,728

were separated from the others, it was immediately observed that in every case the Land Economic Inventory acreages were lower than those observed in the field.

Because this is true with regard to half of the sample, it may be assumed that it is substantially true with regard to half the universe represented by these five towns. After that assumption is made, the next step is to devise some means by which Land Economic Inventory acreages may be used to make estimates of the total wet land acreage in each of the one hundred and forty "much decrease" towns not chosen as sample units. This is most easily done by drawing a trend line on a scattergram plot of actual acreages and Land Economic Inventory acreages (Fig. 2). The exact position taken by this trend line is determined by computing the "least squares." Such a line is the best possible straight trend line for expressing the relationship which exists. The same computation can serve as a base for deriving an empirical formula which expresses the relationship in mathematical terms.

In using this device for making estimates, the Land Economic Inventory acreage of wet land in an individual town is found on the bottom line and a perpendicular is projected to the point where it intersects the trend line. The estimate is then read from the vertical axis at the height indicated by the intersection. The formula expressed by the nomograph (Fig. 2) is $T = 1.59X - 3.2$, with T equaling the estimate in hundreds of acres of wet land and X representing the Land Economic Inventory acreage of wet lands in hundreds. Formulas expressing the relationship between actual and Land Economic Inventory acreages in the "little decrease," "much decrease," southern, middle, and northern towns appear in Table V. In

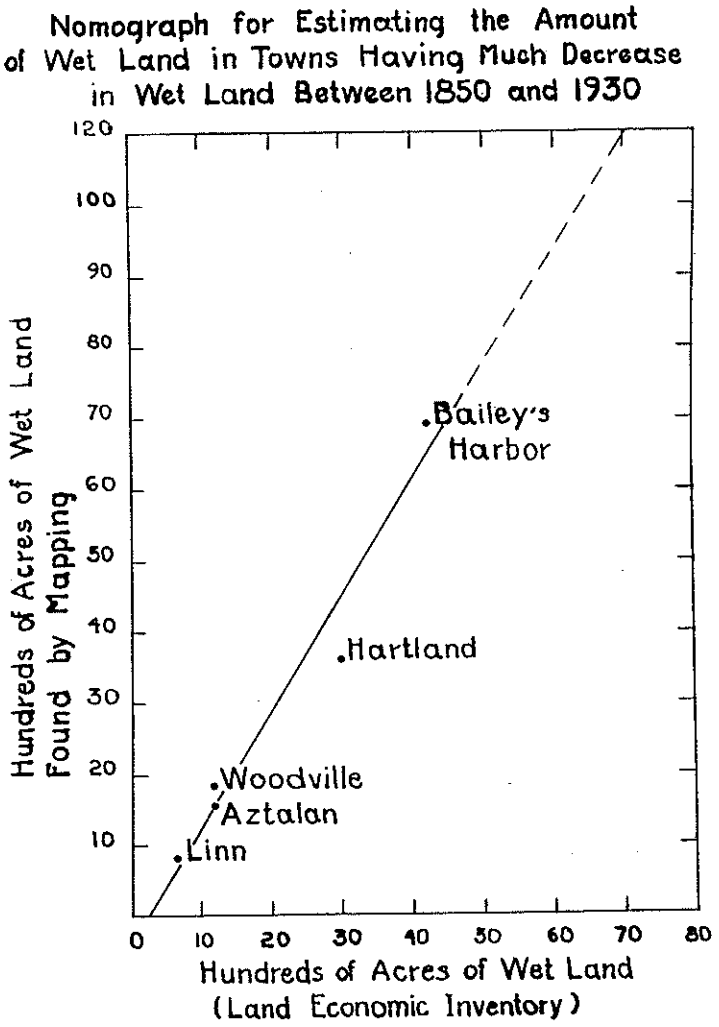

FIG. 2

TABLE V

SUMMARY OF RELATIONSHIP BETWEEN LAND ECONOMIC INVENTORY AND ACTUAL ACREAGES OF WET LAND

Group of sample towns	Land Economic Inventory acreage of wet land	Actual acreage of wet land found in the field	Relationship as expressed by prediction formula*
Much-decrease towns Aztalan, Bailey's Harbor, Hartland, Linn, Woodville	10,271	14,728	T = 1.59 X – 3.2
Little-decrease towns Dunn, Lowell, Nepeuskum, Oconomowoc, West Bend	23,889	22,463	T = .906X + 1.7
Southern towns Aztalan, Dunn, Linn, Oconomowoc	7,460	8,505	T = .867X + 5.1
Middle towns Lowell, Nepeuskum, West Bend	18,288	16,341	T = .96 X – 4.1
Northern towns Bailey's Harbor, Hartland, Woodville	8,412	12,345	T = 1.62 X – 4.2

* T equals the estimate of wet land in hundreds of acres, and X equals the Land Economic Inventory acreage of wet land in hundreds.

making an estimate of wet land acreage in a town not chosen as a sample, two of the five formulas were used. The choice of formulas was determined by the classi-

TABLE VI

ESTIMATES OF WET LAND ACREAGES IN THE SAMPLE TOWNS (IN HUNDREDS OF ACRES)

Sample town	Land Economic Inventory acreage	Much or little decrease	First estimate, according to much or little decrease formula	Southern, middle, or northern	Second estimate, according to geographical location	Final estimate (first and second estimates averaged)	Actual acreage (writer's field maps)
						T*	Y*
Aztalan	12.0	M	15.9	S	15.5	15.7	15.6
Bailey's Harbor	42.3	M	64.1	N	64.3	64.2	69.0
Dunn	32.1	L	30.7	S	32.9	31.8	27.5
Hartland	29.9	M	44.4	N	44.2	44.3	36.0
Linn	6.6	M	7.3	S	10.8	9.0	8.2
Lowell	115.5	L	106.3	M	106.8	106.6	110.1
Nepeuskum	54.9	L	51.4	M	48.6	50.0	40.8
Oconomowoc	23.9	L	23.3	S	25.8	24.6	33.8
West Bend	12.5	L	13.0	M	7.9	10.4	12.5
Woodville	11.9	M	15.7	N	15.1	15.4	18.4
Total	341.6		372.1		371.9	372.0	371.9

* Probable error of estimate (Y–T) = 620 acres; standard error of estimates (0.6745 times 620) = 418 acres. See fn. 11.

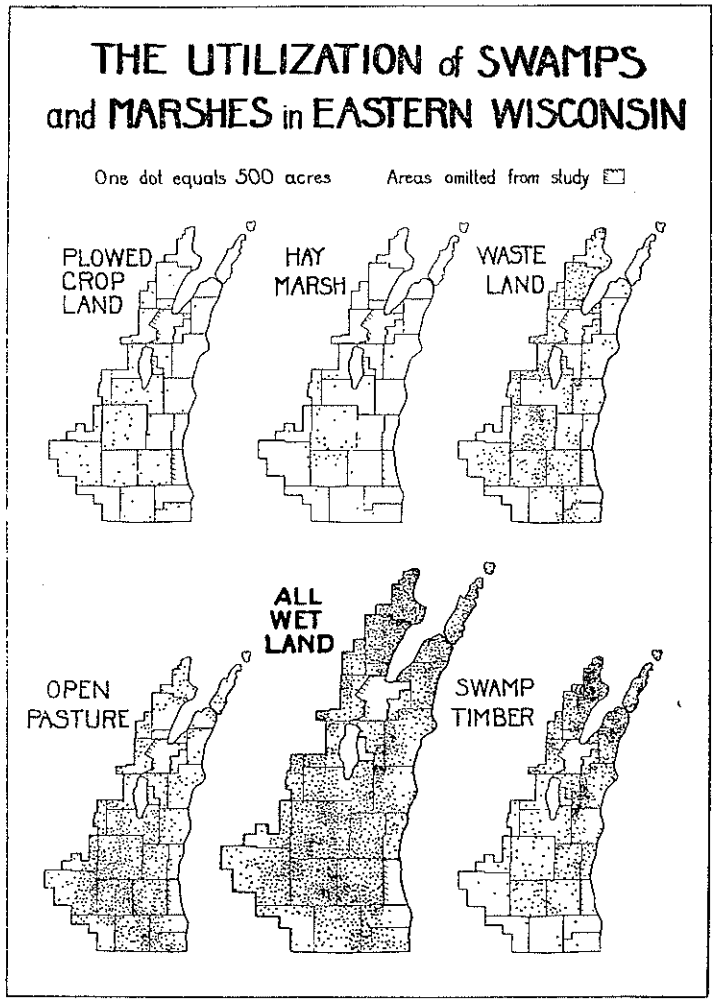

FIG. 3

fication of the town as showing "much" or "little" decrease and its southern, middle, or northern location. The estimates obtained from the two formulas were averaged to make a final estimate. County estimates and estimates for eastern Wisconsin as a whole were made by adding town estimates (Table VI).

TABLE VII

ESTIMATED ACREAGES OF WET LAND IN VARIOUS USES IN EASTERN WISCONSIN

Counties and partial counties in eastern Wisconsin	Swamp	Open pasture	Marsh hay	Cropland other than hay marsh	Waste-land*	All wet land
Brown	11,000	1,300	0	680	6,770	19,750
Calumet	14,000	4,300	350	500	250	19,400
Columbia	2,000	12,700	490	760	−250	15,700
Dane	2,000	36,800	1,620	3,920	17,560	61,900
Dodge	9,000	52,900	7,240	6,900	45,510	121,550
Door	50,000	7,000	100	40	1,860	59,000
Fond du Lac	10,000	31,900	780	5,570	9,100	57,350
Green Lake	1,000	5,800	730	720	7,550	15,800
Jefferson	14,000	42,100	5,470	2,200	19,930	83,700
Kenosha	600	14,600	260	1,140	6,050	22,650
Kewaunee	33,000	3,800	0	710	290	37,800
Manitowoc	38,000	9,300	370	230	4,950	52,850
Marinette	52,000	7,900	0	60	6,090	66,050
Oconto	43,000	6,900	120	470	16,760	67,250
Outagamie	16,000	6,700	140	1,080	5,780	29,700
Ozaukee	8,000	2,700	130	50	1,220	12,100
Racine	800	11,900	10	180	3,460	16,350
Rock	500	10,700	610	80	−2,140	9,750
Shawano	9,000	4,000	0	820	2,980	16,800
Sheboygan	16,000	10,100	40	1,030	9,380	36,550
Walworth	1,000	30,500	300	2,210	8,840	42,850
Washington	18,000	17,600	450	1,100	3,850	41,000
Waukesha	10,000	34,400	360	3,300	12,990	61,050
Winnebago	2,000	7,200	1,100	1,000	10,900	22,200
Total	360,900	373,100	20,670	34,750	199,680	989,100

* The negative acreages listed for Columbia and Rock counties should be no cause for alarm. As illustrated in Table XII, estimated wasteland acreages result when estimates of utilized land are subtracted from the previously made estimate of total wet land. Either the estimates of total wet land were low, or the estimates of some of the uses were high. In any event, the counties do not actually have much wasteland. The situation is analogous to many weather forecasts. For instance, "moderate north winds" are predicted but slight south winds result. This often happens near a front. In the case of these wasteland estimates the "front" is the boundary of eastern Wisconsin which runs through these two counties.

Because it is well to know how accurate estimates made in this manner are, the reliability of the method was tested by comparing actual and estimated acreages of wet land in the sample towns. Table VI, in addition to illustrating the application of the prediction method, contains the necessary data for testing its accuracy. The standard error is 619 acres and the probable error is 418 acres.[11]

[11] Wherever errors of estimate are stated in this paper, use is made of N-2 degrees of freedom. It is felt, though, that this procedure actually yields errors of estimate which are too large. See Frank Yates, *Sampling Methods for Censuses and Surveys* (London: Charles Griffin and Company, 1949), p. 192.

There is no reason to expect that the over and under estimates of wet land would not distribute themselves in a random fashion with regard to both magnitude and geographical location. If it may be assumed that such scattering did occur, the dot map of all wet land (Fig. 3) and the tabulation of county estimates (Table VII) should be quite accurate. The same reasoning applies to the dot maps, and tabulations of individual uses argue for their accuracy as well.[12]

SWAMP

There are about 361,000 acres of swamp in eastern Wisconsin (Table VII). Although much of this land has been cleared from time to time, it has usually been allowed to grow back to trees. Most of the information used in making the map of swampland was available from the Land Economic Inventory, and, except for minor adjustments, was used in its original form. Swamps usually lie in the northern and eastern parts of the region (Fig. 3). Other wet land uses are more common in the western and southern portions.

OPEN PASTURE

Predictions concerning the amount and distribution of open wet pasture rest upon relationships existing in the sample towns between open pasture acreage and two categories of information available for all towns. Well over three quarters of all wet pasture found in the sample was located on surface which is given the designation of "grass marsh" by the Land Economic Inventory. Furthermore, no grass marsh was discovered which was not in pasture. Thus, estimates of grass marsh made by the Land Economic Inventory contain some but not all of the wet open pasture. The town assessors' records list the number of acres of "pasture other than wooded or plowed." Wet open pasture is of course included here, but so is such other land as lanes, stump pasture, and rough upland pasture.

If an estimate is made of grass marsh acreage and added to the assessors' acreage of "pasture other than wooded or plowed," the result is an index number which has a highly significant relationship to actual acreages of poorly drained pasture (Table VIII). The estimate of wet pasture acreage was made by the use of a nomograph which expressed visually the equation $T = .487X - 2.2$, with T equaling the estimate in hundreds of acres and X equaling the index number in hundreds.

A very high degree of confidence can be placed in the estimates of the amount and distribution of wet pasture (Table VII and Fig. 3). The county acreage of grass marsh, which is the largest contributor to total wet pasture acreage, correlates to the extent of 0.97 with the wet pasture estimates (Table IX). If the over estimates had clustered in some counties and under estimates in other counties, such a high value of the coefficient of correlation could not have resulted.

[12] The first copies of the dot maps had town lines and were based on town estimates. Town lines were not drafted on the final plate because they would have detracted from the visual quality of the illustration. The towns in Wisconsin are arranged in a more or less rectangular pattern, and the laws of probability favor an error of estimate in one town being compensated for in one of the towns which adjoin or corner on it.

TABLE VIII

DATA RELATED TO WET PASTURE ACREAGE IN THE TEN SAMPLE TOWNS

Sample town	Hundreds of acres of pasture "other than wooded or plowed" (Assessors')	County's per cent of wet land in grass marsh (Land Economic Inventory)	Hundreds of acres of wet land (Land Economic Inventory)	Hundreds of acres of grass marsh (1½ times III)	Index number (I plus IV) X	Hundreds of acres of wet pasture T = .487X − 2.2 T	Hundreds of acres of wet pasture recorded in the field
	I	II	III	IV	V	VI	VII
Aztalan	10	43	12	5	15	5	12
Bailey's Harbor	8	3	42	1	9	2	1
Dunn	25	49	32	16	41	18	8
Hartland	19	2	30	1	20	8	5
Linn	15	48	7	3	18	6	7
Lowell	74	32	115	37	111	52	58
Nepeuskum	43	23	55	13	56	25	16
Oconomowoc	19	63	24	15	34	14	17
West Bend	4	23	12	3	7	1	5
Woodville	10	13	12	2	12	4	6
Total	227		341	96	323	135	135

Coefficient of correlation (X and Y) = 0.93.
Standard error of estimates (Y − T) = 619 acres.
Probable error of estimate (619 times .6745) = 418 acres.

TABLE IX

RELATIONSHIP BETWEEN ESTIMATED WET PASTURE ACREAGES AND LAND ECONOMIC INVENTORY ACREAGES OF GRASS MARSH IN THIRTEEN COUNTIES

County	Grass marsh acreage (Land Economic Inventory)	Estimate of wet pasture acreage (Table VII)
	X	Y
Dodge	40,161	52,900
Door	1,157	7,000
Fond du Lac	23,927	31,900
Jefferson	33,025	42,100
Kenosha	10,855	14,600
Kewaunee	509	3,800
Manitowoc	3,397	9,300
Ozaukee	1,392	2,700
Racine	10,095	11,900
Sheboygan	5,360	10,100
Walworth	17,342	30,500
Washington	9,903	17,600
Waukesha	35,224	34,400

Coefficient of correlation (X and Y) = 0.97.

MARSH HAY

Information on wild hay acreages is available from the assessors' reports. If there is any wild hay harvested in eastern Wisconsin which is not marsh hay, field observation did not reveal it. It is therefore considered permissible to use "wild hay" acreages as reported by the assessors to indicate "marsh hay."

CROPLAND

Predictions regarding the amount and distribution of cropland rest upon the inverse relationship of this category of land use to the log of the percentages of farm land in trees (Table X). Of course, neither of these two ingredients of the

TABLE X

DATA RELATED TO PERCENTAGES OF WET LAND IN CROPS IN THE TEN SAMPLE TOWNS

Sample town	Actual percent of wet land in crops, including wild hay	Percent of farm land in trees	Log of percent of farm land in trees	Estimated percent of wet land in crops, including wild hay
	Y		X	T
Aztalan	7.5	5.0	.70	9.1
Bailey's Harbor	0	29.6	1.47	0
Dunn	1.7	8.7	.94	5.6
Hartland	2.2	15.2	1.18	1.9
Linn	4.5	7.7	.89	6.3
Lowell	15.4	2.8	.45	12.7
Nepeuskum	10.1	3.7	.57	10.9
Oconomowoc	10.8	6.1	.79	7.7
West Bend	1.8	16.1	1.21	1.8
Woodville	6.0	7.9	.90	6.1

Coefficient of correlation (X and Y) = – 0.90.
Estimates are made by the formula T = – 1.45X + 19.2.
Standard error of estimate (Y – T) = 2.17 percent of all wet land.
Probable error of estimate (2.17 times .6745) = 1.46 percent of all wet land.

landscape may be expected to cause the other; nevertheless they are closely related. In the southern part of the region, trees almost everywhere occupy only the swamps or steep slopes. Here marshes are the most important potential source of additional cropland. In the north, trees may still be found growing on well drained upland which is level enough for crops, and there is at present little reason for developing cropland through drainage.

Some census data on artificial drainage of land[13] show a very close relationship to county estimates of wet cropland (Table XI). As Leslie Hewes has pointed out, one should be aware of the exact meanings of the column headings before drawing any conclusions from the figures.[14] In Wisconsin, where whole forty-acre

[13] The figures of the X column of Table XI were obtained by adding items 2 and 6 from Table II, pp. 455–458 of the *16th Census of the U. S.*, 1940, *Drainage of Agricultural Lands.*

[14] Leslie Hewes, "Drained Land in the United States in the Light of the Drainage Census," *The Professional Geographer*, Vol. 5, No. 6 (Nov., 1953), pp. 6–12.

tracts are usually included in drainage districts regardless of the amount of poorly drained land in each tract, the number of miles of drain is a preferred indicator of the amount drained. This is especially true in much of the southern half of eastern Wisconsin, where most of the subsoil is gravel and where most of the draining took place.

TABLE XI

RELATIONSHIP BETWEEN ESTIMATED WET LAND CROP ACREAGES AND MILES OF DRAINAGE DITCH AND TILE (U. S. CENSUS) IN ELEVEN COUNTIES

County	Miles of drain 1940	Estimated acreages of wet land in crops including wild hay (Table VII)
	X	Y
Dodge	279.8	14,140
Fond du Lac	41.6	6,350
Jefferson	197.9	7,670
Kenosha	41.9	1,400
Manitowoc	4.3	600
Ozaukee	26.8	180
Racine	120.8	190
Sheboygan	21.1	1,070
Walworth	46.1	2,510
Washington	16.1	1,550
Waukesha	39.7	3,660
Total	836.1	39,320

Coefficient of correlation (X and Y) = 0.83.

The value of 0.83 for the coefficient of correlation between miles of drain and estimates of wet cropland indicates that an added measure of confidence may be placed in these figures (Table VII). The placing of dots on the map showing wet cropland was accompanied by an element of subjective judgement, however, because fewer than thirty-five towns had more than 500 acres estimated in this use.

WASTELAND

Wasteland is so called because it has no agricultural use in the usually accepted sense of the word. On the whole it is the wettest of all marshes. In fact, if such land were only a little drier it would probably be used for pasture. The vegetation types which contribute to this category of land are:

1. Cattail, which always grows in places too wet for any agricultural use.
2. Sedge, which makes up most of the wasteland, but in places is used for pasture or marsh hay.
3. Brush, largely willow and tag alder, which is usually wasteland, but in places is used for pasture.
4. Miscellaneous minor types such as wild cranberry, leather leaf, and weedy peat.

The best way found to predict the amount and distribution of wasteland was to add the acreage estimates of all other uses and subtract that sum from the total

TABLE XII

ESTIMATED ACREAGES OF VARIOUS WET LAND USES AND ACTUAL ACREAGE OF WASTELAND IN THE TEN SAMPLE TOWNS

Sample town	Swamp	Open pasture	Crops including wild hay	Sums of I, II, and III	All wet land	Waste-land (V minus IV)	Actual waste-land acreage
	I	II	III	IV	V	VI	VII
Aztalan	220	510	140	870	1,570	700	91
Bailey's Harbor	5,390	220	0	5,610	6,420	810	458
Dunn	100	1,770	180	2,050	3,180	1,130	1,832
Linn	20	650	60	730	900	170	115
Hartland	3,650	750	90	4,490	4,430	−60	117
Lowell	840	5,180	1,350	7,370	10,660	3,290	2,730
Nepeuskum	520	2,500	550	3,570	5,000	1,430	2,085
Oconomowoc	480	1,430	190	2,100	2,460	360	602
West Bend	420	120	20	560	1,040	480	129
Woodville	940	360	90	1,390	1,540	150	159
Total	12,580	13,490	2,670	28,740	37,200	8,460	8,318

Coefficient of correlation (VI and VII) = 0.87.

Standard error of estimate, using VI as estimate of VII, is 515 acres. The probable error is 347 acres.

amount of wet land. The remainder was taken as the estimate of wasteland acreage. Pertinent information necessary to make wasteland estimates for the sample is gathered together from previous sections of this paper and listed in Table XII. This simple method of estimating the amount of wasteland yields encouraging results,

TABLE XIII

RELATIONSHIP BETWEEN ESTIMATED WASTELAND ACREAGES AND LAND ECONOMIC INVENTORY ACREAGES OF SELECTED TYPES OF LAND COVER IN THIRTEEN WHOLE COUNTIES

County	Estimated acreage of waste (Table VII)	Total acreage of selected land cover types, Land Economic Inventory*	Marsh hay acreage (Table VII)	X_1 minus marsh hay acreage
	Y	X_1		X_2
Dodge	45,510	77,257	7,240	70,017
Door	1,860	5,156	100	5,056
Fond du Lac	9,100	28,333	780	27,553
Jefferson	19,930	30,730	5,470	25,260
Kenosha	6,050	9,222	260	8,962
Kewaunee	290	2,963	0	2,963
Manitowoc	4,950	8,919	370	8,549
Ozaukee	1,220	6,101	130	5,971
Racine	3,460	4,159	10	4,149
Sheboygan	9,380	13,528	40	13,488
Walworth	8,840	17,815	300	17,515
Washington	3,850	14,517	450	14,067
Waukesha	12,990	10,584	360	10,224
Total	127,430	229,284	15,510	213,774

* Includes tag alder and willow, cattail, sedge marsh, weedy peat, and other minor open marsh types.

Coefficient of correlation (X_2 and Y) = 0.95.

as evidenced by the relatively low values of the probable and standard errors of estimate (484 and 326 acres, respectively).

In Table XIII the county estimates of wasteland for the thirteen whole counties of eastern Wisconsin are compared with Land Economic Inventory acreages of all types of vegetation cover which contribute to the wasteland total. The coefficient of correlation (0.95) indicates that the over and under estimates must have distributed themselves quite evenly throughout the region. In support of the map of waste-land (Fig. 3) it can be pointed out that some large and well-known marshes appear on it. Three such large areas of wasteland are Horicon Marsh in north central Dodge County, Sheboygan Marsh in northwest Sheboygan County, and marshes associated with the "Four Lakes" in Dane County. Readers having a knowledge of other specific large areas of unutilized marsh will most likely be able to locate them on the map.

SUMMARY

Total Wet Land. The predictions of total wet land are based on two surveys which took note of the amount and distribution of wet land. Information from these two sources was supplemented by knowledge gained during the mapping of nearly forty thousand acres in the field. The probable error of estimate of 619 acres per town should not cause undue concern, because the acreage which changes from marsh surface to open water and back again within a year's time may well exceed these limits in some towns.

Swamp. Indicated acreages of swamp are based on the Land Economic Inventory which took special note of all types of swamp.

Hay Marsh. The amount and distribution of hay marsh is available from the assessors' records.

Open Pasture, Cropland, and Wasteland. The methods used to make estimates of these uses are common to other sciences but are just coming into use in geographic research. An abundance of data made it possible to conduct an "independent audit" of these figures, the results of which were highly encouraging.

It is believed that the map showing distribution of land use (Fig. 3) is about as accurate as one which might have been made *at this scale* had the whole million acres of swamp and marsh been mapped in the field. The approach here demonstrated would seem to be applicable in many fields of geographic research. It is most needed in studies at the intermediate scale, or what Preston James would call the chorographic scale.[15] Good use is made of techniques developed by micro-geographers, and along with this are demonstrated new uses for data already compiled by others.

[15] Preston E. James, "The Terminology of Regional Description," *Annals*, Association of American Geographers, XXIV (1934), pp. 79–92. Also: "Toward a Further Understanding of the Regional Concept," *Annals*, Association of American Geographers, XLII (1952), pp. 195–222.